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DESIGN AND STATIC ANALYSIS OF ELECTROMAGNETIC SHOCK ABSORBER USING ELECTROMAGNETIC INDUCTION

ANMOL MAHAJAN & PRATHAM CHHABRA

Department of Mechanical and Automation Engineering, Maharaja Agrasen Institute of Technology,
New Delhi, India

ABSTRACT

Suspension is the main part of the automobile and shocks are used to make the ride more comfortable even on uneven road. This electromagnetic shock have been designed in order to improve the mechanical efficiency as compared to oil shockers and at the same time providing adjustability as per loads and road conditions, the economic consideration of the design & the size of the shocker is most suited to its use not only in auto industry but also in various machines. The designed shocker has been observed be effectively sustainable and reproducible. The modeling part was carried out in ultimate tensile machine for checking and found to have noticeable result according to the design.

KEYWORDS: Capacitor, Permanent Magnet, Electromagnet

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Original Article

INTRODUCTION

Goldner et. al [1] proposed electromagnetic shock absorbers to transform the energy dissipated in shock absorbers into electrical power. Gupta [2] has studied the available energy from shock absorbers as cars and trucks are driven over various types of roads. Graves et. al [3] studied electromagnetic regenerative damping. They mention that energy regeneration is small and may be relevant only for electric vehicles. They also propose ways to amplify the motion of the shock in order to increase recoverable energy which on the other hand may have a negative effect on vehicle dynamics. Another interesting observation made by them is that device output voltage must be large enough to overcome the barrier potential of the storage device. Suda and Shiba [4] studied a hybrid suspension system where active control is adopted at low frequency and passive control by energy regenerative damper is adopted at high frequency. Fodor and Redfield [5] tried to design a regenerative damper. However, they came across the design limitation of amplifying mechanical devices input force which is necessary because available energy is low and a threshold for energy storage exists. Karnopp [6] studied the electromagnetic involved in designing permanent magnet linear motors used as variable mechanical dampers. However, until now no practical electromagnetic shock absorbers have been designed for automotive or truck usage. The shockers as designed by us have not been attempted by different scientists or engineers our shockers contain mainly three assemblies: permanent magnet, coil (electromagnet), capacitor which collectively work as shocker or shock absorber.

CONSTRUCTION

A mechanical shocker resembles a telescopic suspension i.e. including slider tube and fork tube. A

Permanent strong magnet with same inner diameter of slider is fixed at the base of fork tube. A capacitor plate is fixed just above the permanent magnet connected with positive terminal and an Electromagnet (inductor) is fixed at the ends of fork tube and another capacitor plate is attached in front of it connected with negative terminal. The polarity of electromagnet is made same as to that of permanent magnet so that they repel each other. The whole system is air tight thus a dielectric medium is also added to the system so as to change the capacitance. The whole system is connected to a stock 12V battery that is being supplied by the car/bike manufacturer itself so as to make the circuit economical and ready to use (figure 1 & 2).

THEORY

The main theory behind these shockers is that when there is loading on the shockers the distance between the capacitor plate changes due to which the capacitance (C) of the capacitor changes i.e.

$C = k_d \epsilon_0 \ A/d$

Due to change in distance the charge (q) changes since:

$Q = c \ v$

$dQ = dC \ v$

And hence change in charge (dQ) changes the current (I) with respect to the change in reaction time (dt)

$I = dQ/dt$

Due to which the magnetic field of the electromagnet changes.

$dB = \mu n \ dI$

(μ is permeability of the medium)

dB is adjusted according the magnetic field strength of the permanent magnet, so that the repulsive/Attractive force generated during the process should work as explain further. As distance decreases between the plate electromagnet reached closer to the permanent magnet according to the Lenz law. Electromagnet reaches the distance that is limited (calculated) by us it changes the polarity i.e. opposite to that of permanent magnet due to which the repulsive force acts which help the upper piston to again retain its normal (ideal) position. As the force (load) increases the shocker automatically adjust its magnetism and hence protect the machine or automobile against any shock. And also the length between the plates can be adjusted by the user according to the stiffness required, which makes it user friendly and tunable.

NOMENCLATURE

C = capacitance of the capacitor

dI = change in the current in circuit

dB = change in magnetic field

dt = reaction time of the shocks

dQ = change in charge of capacitor

n = no. of turns of coil of the electromagnet

A = area of the capacitor plates

d = distance between the capacitor plates i.e. = 10 cm

dx = change in the distance between the capacitor plates i.e. = 6-7 cm

V = voltage supply i.e. = 12V dc

$v_{s\,=}$ velocity of the shock movement

k_d = relative permittivity or dielectric constant

k_s= spring rate

μ = permeability (here taken for copper) = 1.25 x 10^{-6} h m^{-1}

ϵ = permittivity of the dielectric = $k_d\ \epsilon_0$

CALCULATIONS (STATIC CALCULATION)

Taking a case to show the change in various identities of the suspension like capacitance , magnetic field , current and also the magnetic field strength of the permanent magnet used .Taking the case when the shocks are pressed the distance between the plates decreases as due to which the capacitor changes

$c + dc = k\epsilon_0\ A\ /d+dx$

$dc= k\epsilon_0\ Adx\ /\ d^2$

$dQ = dc * V = (k\epsilon_0\ A\ dx/\ d^{2)}.V$

$dQ\ /\ dt = I$

$I = k_d\epsilon_0 A\ dx/\ d^2 dt = (k_d\epsilon_0\ A\ dx\ V/\ d^2 dt)$

as dt = reaction time of the shock which is quite a small quantity therefore can be neglected where ever possible or can be taken as =.01sec

$dB = u_*\ n\ dI = u_*\ n\ (k_d\epsilon_0 A\ dx\ V/\ d^2 dt)$

$dB = \mu\ n\ (k_d\ \epsilon_0\ A\ dx\ V/\ d^2 dt)$

Now B (magnetic field) which is calculated through this equation will give us strength of magnetic field of the permanent magnet used so as to perform in the appropriate way. On the ideal state the when there is no change in the distance of the capacitor plate then the magnet field would be this

Now, force due to magnetic field

$dF = qv_s\ dB$

$dF = (\epsilon_0\ k_d\ A/d)\ V * v_s * \mu\ n\ (k_d\ \epsilon_0\ A\ dx\ V/\ d^2 dt)$

Since dt is very small therefore, can be neglected or can be taken as =.01sec

$$dF = V^2\ \epsilon_0^{\,2}\ A^2\ v_s\ dx\ \mu\ n\ k_d^{\,2}/dt\ d^3 \qquad (1)$$

Now,

Spring Force (dF) = $-k_s\ dx$ (2)

Comparing 1 & 2 we get

$-k_s\ dx = V^2\ \epsilon_0^2\ A^2\ v_s\ dx\ \mu\ n\ k_d^2/dt\ d^3 = V^2\ \epsilon_0^2\ A^2\ a_s\ dx\ \mu\ n\ k_d^2/\ d^3$ (3)

Now dimensional formula of ideal spring rate= $M^1\ L^0\ T^{-2}$

Now dimensional formula of other factors

$a_s = M^0\ L^1\ T^{-2}$

$A = M^0\ L^2\ T^0$

$\epsilon = k_d\ \epsilon_0 = M^{-1}\ L^{-3}\ T^4\ I^2$

$\mu = M^1\ L^1\ T^{-2}\ I^{-2}$

$V = M^1\ L^2\ T^{-3}\ I^{-1}$

Putting these in the equation we get

$k_s = (M^0\ L^1\ T^{-2})\ (M^0\ L^2\ T^0)^2\ (M^{-1}\ L^{-3}\ T^4\ I^2)^2\ (M^1\ L^1\ T^{-2}\ I^{-2})\ (M^1\ L^2\ T^{-3}\ I^{-1})^2\ /\ L^3$

$k_{s\ =}\ M^1\ L^1\ T^{-2}$ (4)

Thus this equation tell us that the spring rate depends on change in distance between the plates of capacitor i.e. when the distance between plates start decreases it increases the spring rate. Which is required for this shock as stated in construction and theory part? And thus the working of our shock is proven dimensionally. For static force calculation we make a free body diagram of shock during any bump due to which there is compression and expansion going through it (figure 3) showing the change in magnetic force due to change in charge because of change in capacitance and change in magnetic field or strength of electromagnet. Now by calculating the voltage in a capacitor and electromagnet circuit, we can calculate the charge in the circuit by which we can calculate velocity of the piston during either compression or expansion. And thus can calculate the spring rate during the process.

For checking the working of our shock we have installed shock according to the construction stated above in the old fox float 2 shocks shown in (figure 4 & 5).and performed the compression test on the ultimate tensile machine. It was found with noticeable results according to our theory and calculation as stated above. The overall research and design of the shock proves that it works according to our design and concluded successful.

CONCLUSIONS

It is observed that this type of shock would help the industry to make the ride more efficient and comfortable, economical and customizable at the same time. Powerful magnets will be necessary for heavier loading as more magnetic force would be required and also a dielectric should be selected according to the load.

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APPENDICES

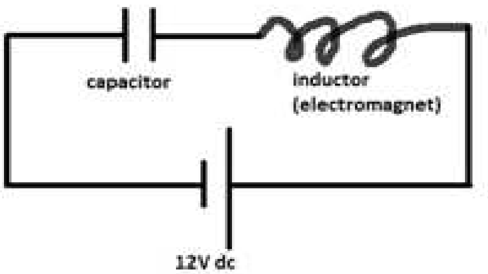

Figure 1

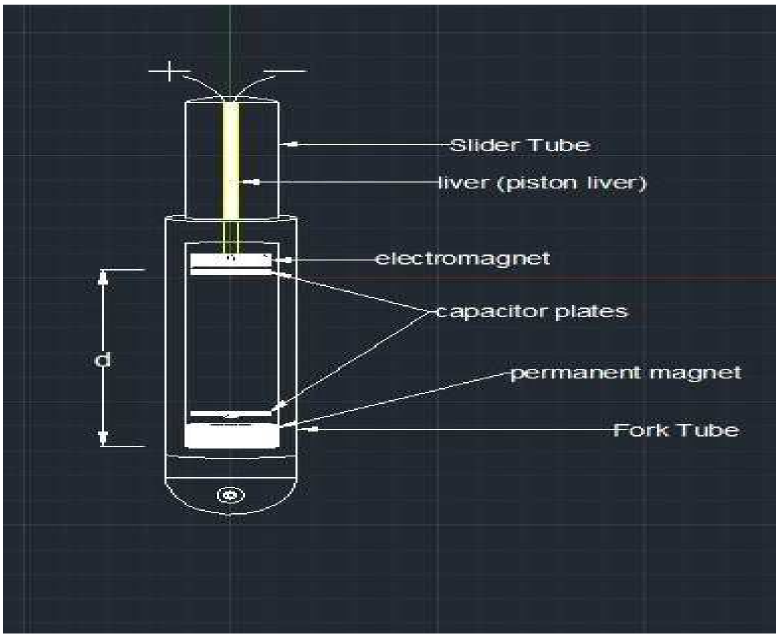

Figure 2

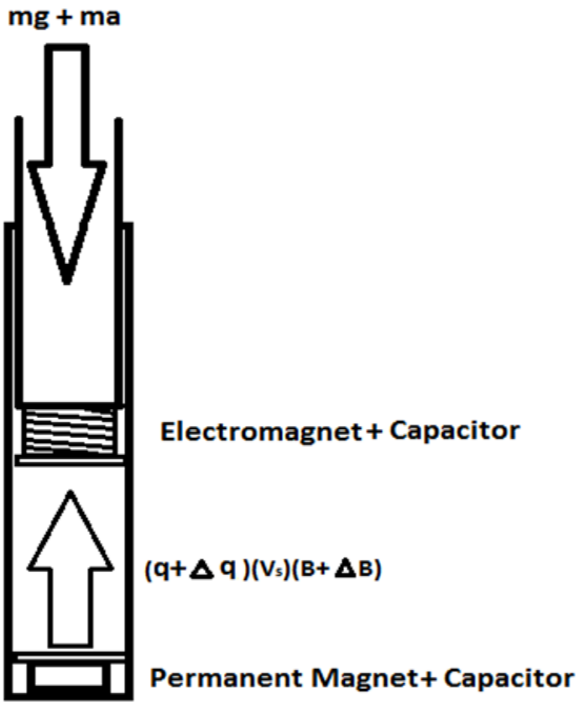

Figure 3

Figure 4

Figure 5